

**Fishery Data Series No. 16-46**

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# **Chinook Salmon Escapement and Run Timing in the Gulkana River, 2013–2015**

by  
**Corey J. Schwanke**

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December 2016

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Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries



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Weights and measures (metric)		General		Mathematics, statistics	
centimeter	cm	Alaska Administrative Code	AAC	<i>all standard mathematical signs, symbols and abbreviations</i>	
deciliter	dL	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	alternate hypothesis	H <sub>A</sub>
gram	g	all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.	base of natural logarithm	<i>e</i>
hectare	ha	at	@	catch per unit effort	CPUE
kilogram	kg	compass directions:		coefficient of variation	CV
kilometer	km	east	E	confidence interval	(F, t, $\chi^2$ , etc.)
liter	L	north	N	correlation coefficient (multiple)	CI
meter	m	south	S	correlation coefficient (simple)	R
milliliter	mL	west	W	covariance	<i>r</i>
millimeter	mm	copyright	©	degree (angular)	cov
		corporate suffixes:		degrees of freedom	°
		Company	Co.	expected value	df
		Corporation	Corp.	greater than	<i>E</i>
		Incorporated	Inc.	greater than or equal to	>
		Limited	Ltd.	harvest per unit effort	≥
		District of Columbia	D.C.	less than	HPUE
		et alii (and others)	et al.	less than or equal to	<
		et cetera (and so forth)	etc.	logarithm (natural)	≤
		exempli gratia (for example)	e.g.	logarithm (base 10)	ln
		Federal Information Code	FIC	logarithm (specify base)	log
		id est (that is)	i.e.	minute (angular)	log <sub>2</sub> , etc.
		latitude or longitude	lat or long	not significant	'
		monetary symbols (U.S.)	\$, ¢	null hypothesis	NS
		months (tables and figures): first three letters	Jan,...,Dec	percent	H <sub>0</sub>
		registered trademark	®	probability	%
		trademark	™	probability of a type I error (rejection of the null hypothesis when true)	P
		United States (adjective)	U.S.	probability of a type II error (acceptance of the null hypothesis when false)	$\alpha$
		United States of America (noun)	USA	second (angular)	$\beta$
		U.S.C.	United States Code	standard deviation	"
		U.S. state	use two-letter abbreviations (e.g., AK, WA)	standard error	SD
				variance	SE
				population sample	Var
					var
Weights and measures (English)					
cubic feet per second	ft <sup>3</sup> /s				
foot	ft				
gallon	gal				
inch	in				
mile	mi				
nautical mile	nmi				
ounce	oz				
pound	lb				
quart	qt				
yard	yd				
Time and temperature					
day	d				
degrees Celsius	°C				
degrees Fahrenheit	°F				
degrees kelvin	K				
hour	h				
minute	min				
second	s				
Physics and chemistry					
all atomic symbols					
alternating current	AC				
ampere	A				
calorie	cal				
direct current	DC				
hertz	Hz				
horsepower	hp				
hydrogen ion activity (negative log of)	pH				
parts per million	ppm				
parts per thousand	ppt, ‰				
volts	V				
watts	W				

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GULKANA RIVER, 2013–2015**

by  
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## ABSTRACT

Counting tower techniques were used to estimate Chinook salmon *Oncorhynchus tshawytscha* escapement at the Gulkana River for 2013, 2014 and 2015. The counting tower was located in the mainstem Gulkana River about 2.5 rkm upstream of the West Fork Gulkana River confluence. The counting tower was operational for all 3 years for the entire Chinook salmon run and a portion of the sockeye salmon *O. nerka* run. The estimated escapement of Chinook salmon was 3,936 (SE = 215; 95% CI = 3,515-4,357) in 2013, 3,478 (SE = 271; 95% CI = 2,947-4,009) in 2014, and 3,738 (SE = 251; 95% CI = 3,246-4,230) in 2015. These numbers do not represent total inriver escapement, just passage above the counting tower site. The date of 50th percentile passage of Chinook salmon varied from 14 July in 2013 to 5 July in 2015. The estimated escapement of sockeye salmon during the counting tower's operational period was 48,024 (SE = 1,834; 95% CI = 44,429-51,619) in 2013, 27,186 (SE = 1,236; 95% CI = 24,763-29,609) in 2014 and 24,624 (SE = 970; 95% CI = 22,723-26,525) in 2015.

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, sockeye salmon, *Oncorhynchus nerka*, Copper River, Gulkana River, counting tower, escapement, run timing

## INTRODUCTION

The Gulkana River drainage (Figures 1 and 2) supports spawning populations of Chinook salmon *Oncorhynchus tshawytscha*, sockeye salmon *O. nerka*, rainbow/steelhead trout *O. mykiss* and Arctic grayling *Thymallus arcticus*. The river is 1 of 6 major spawning tributaries for Chinook salmon in the Copper River drainage and has traditionally supported the largest Chinook salmon sport fishery in the Copper River drainage and Upper Copper-Upper Susitna Management Area (Somerville and Maclean 2014). Annual sport harvest of Gulkana River Chinook salmon peaked in the 1990s, fluctuating between 4,000 and 6,000 salmon (Figure 3). Estimated catch peaked at over 18,000 Chinook salmon in 1997. Catch and harvest has been reduced substantially the last several years due to poorer runs and increased restrictions to the fishery (Somerville and Maclean 2014; Figure 3). In addition to the inriver sport fishery, the Gulkana River Chinook salmon stock is subject to harvest in commercial fisheries located near the mouth of the Copper River and subsistence and personal use (PU) fisheries located in the mainstem of the Copper River. There are no stock-specific estimates of harvest available for these fisheries, but it is believed that the Gulkana River component accounts for a substantial portion of these harvests (Botz and Somerville 2011).

In 2003, the Alaska Board of Fisheries (BOF) amended the *Copper River King Salmon Management Plan* to include a sustainable escapement goal of 24,000 or more Chinook salmon for the Copper River drainage. Inriver abundance is estimated annually by conducting a two-event mark-recapture experiment using a series of four fish wheels and in the Lower Copper River (Piche et al. 2016). Inriver harvest is then subtracted post-season to obtain an estimate of drainage wide escapement. There are no established escapement goals for any of the Copper River tributaries.

The section of the Gulkana River upstream of Sourdough Landing (Figure 2) has been designated by the U.S. Congress as a "wild river," which makes it part of the *National Wild and Scenic Rivers System*. The Bureau of Land Management (BLM) manages the adjacent lands along both banks within this area and has the authority to limit the number of trips per year or number of people per trip. To date, no permit system is in place; however, stakeholders have submitted proposals to the BOF to limit motor boat use.

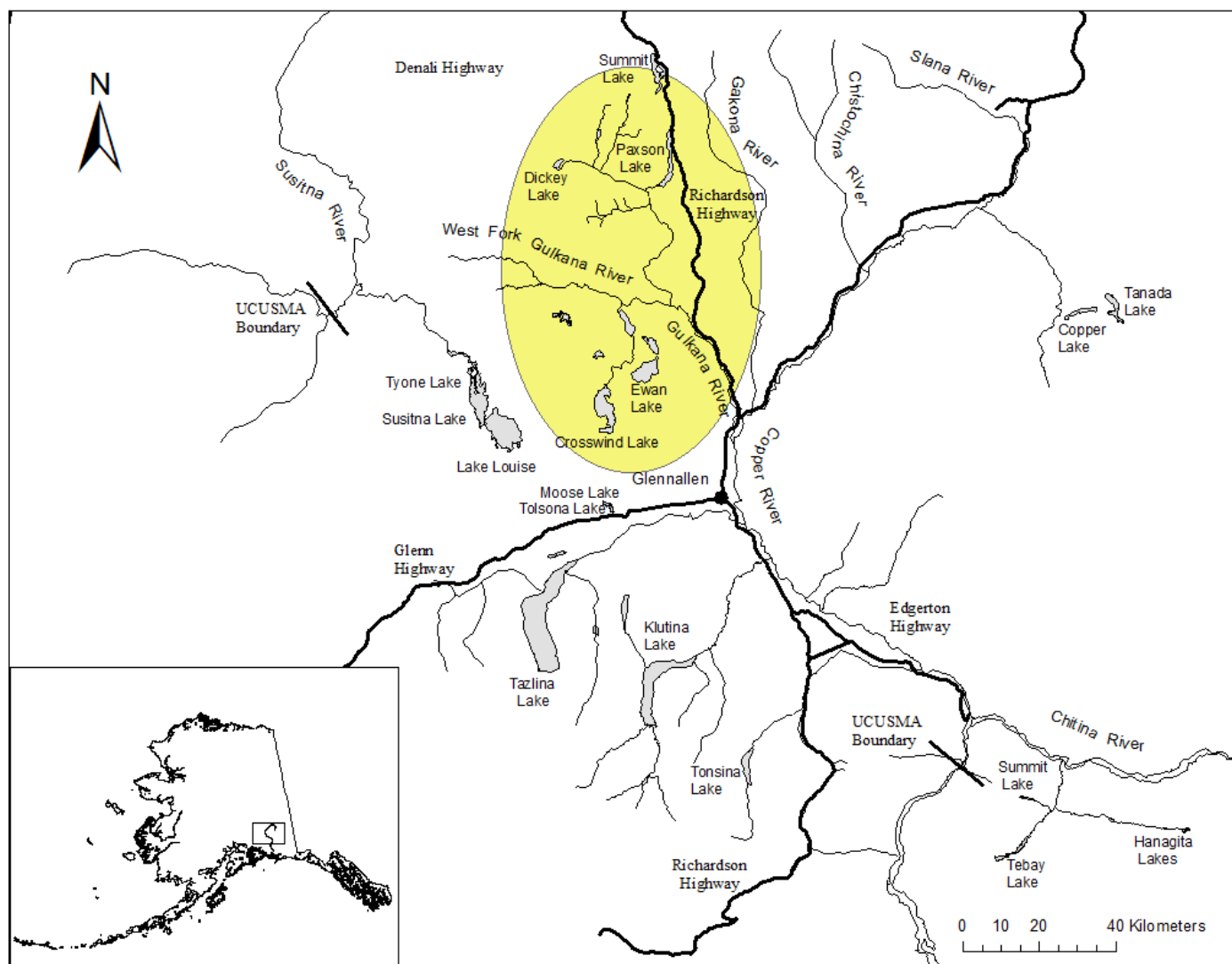


Figure 1.—The Gulkana River (located in the upper center) within the Upper Copper-Upper Susitna Management Area.

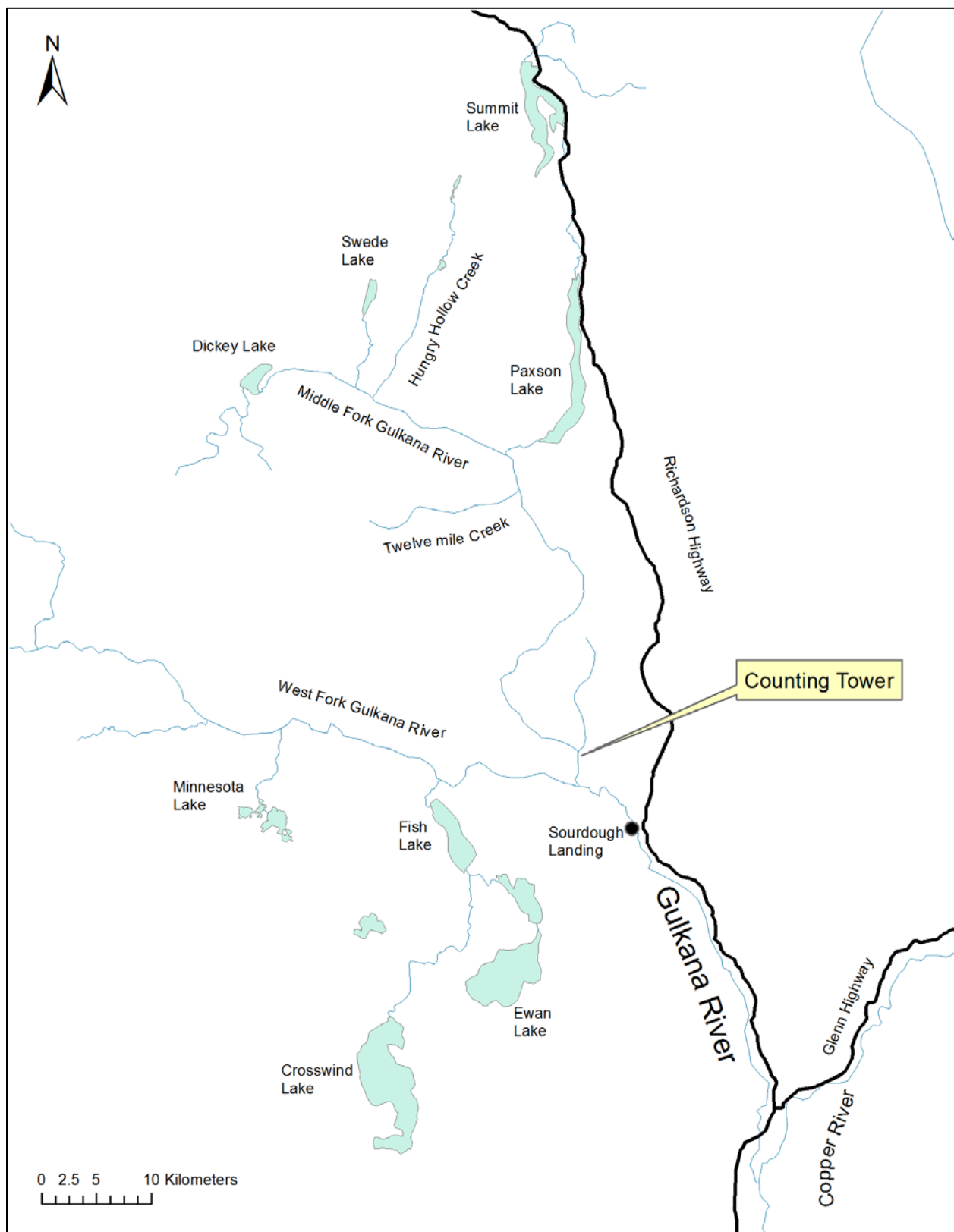


Figure 2.—Map of the Gulkana River with the location of the counting tower.

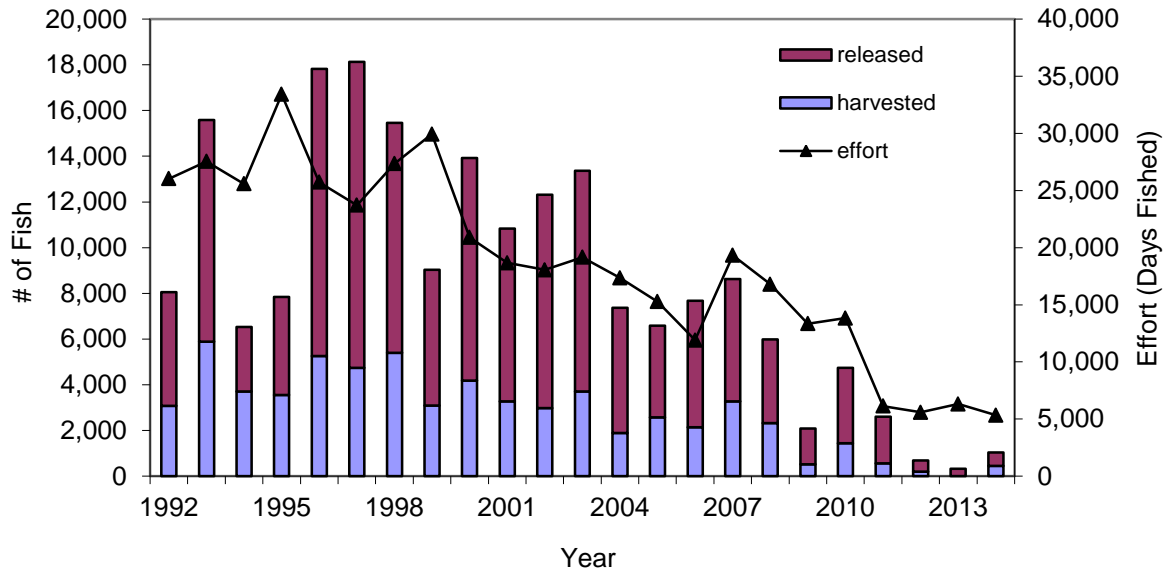


Figure 3.—Number of Chinook salmon harvested and released (the sum is catch), and fishing effort for all species of fish, Gulkana River, 1992–2014. Data from Somerville and Maclean (2014).

In 2002, a multi-year cooperative project was initiated between the Alaska Department of Fish and Game (ADF&G) and BLM to monitor Chinook salmon escapement on the Gulkana River using counting tower techniques. This project had been run successfully for 14 consecutive years (Perry-Plake et al. 2007, Perry-Plake and Antonovich 2009, Perry-Plake and Huang 2011, Maclean 2013; Savereide 2010 and 2011; Taras and Sarafin 2005). The Gulkana River was selected because (1) the stock on average makes up a significant percentage (~20%) of the total Copper River escapement (Savereide 2005), (2) it supports the largest sport fishery in the Copper River drainage (Somerville and Maclean 2014), (3) fishing pressure was relatively high, (4) the accuracy of annual aerial escapement surveys was unknown, and (5) it is the only tributary in the Copper River drainage supporting a substantial Chinook salmon sport fishery that is not glacially occluded.

## OBJECTIVES

The 2013–2015 project objectives were to:

1. Estimate escapement of Chinook salmon, within 15 percent of the actual value 95 percent of the time, upstream of an established counting tower site on the mainstem Gulkana River;
2. Describe inriver run timing for Chinook salmon past the counting tower; and
3. Enumerate sockeye salmon passage at the counting tower during the period of tower operation.

# METHODS

## CHINOOK SALMON ESCAPEMENT

The counting tower was located approximately 72 rkm from the confluence of the Gulkana and Copper rivers and, more precisely, 2.5 km upstream from the confluence of the West Fork and mainstem Gulkana rivers (Figure 2). This location was chosen to avoid the often turbid discharge of the West Fork Gulkana River and it was believed the majority of spawning occurs upstream of this site. A small island splits the mainstem into 2 channels at the tower site. Steel scaffolding platforms approximately 4 m above the water were located on each side of the island to provide a comprehensive view of the entire river (approximately 30 m wide per channel). The towers supported dome-shaped pole frames that were covered on the top and 3 sides with tarps to prevent shadows on the water and to provide the observer with protection from wind and rain. Maximum depth in both channels ranged from 1 to 1.5 m.

To ensure migrating fish were clearly visible, a continuous band of white vinyl panels, approximately 2.5 m wide, was anchored to the river bottom across each river channel. There was also a 2–3 m section of picket weir placed near the base of each tower to ensure no fish were able to pass undetected directly beneath the towers. To ensure optimal viewing conditions, the panels were cleaned of debris, silt, gravel, and fish carcasses between scheduled counts as necessary. During periods of low ambient light, exterior-grade floodlights were used to illuminate the panels across each channel. Once the lights were turned on, they remained on between counts to maintain consistent conditions until no longer needed. This was done to reduce any associated effect that lighting changes may have had on salmon migration.

Six technicians (two 3-person crews) were assigned to enumerate the salmon escapement. Two 10-minute counting periods (one per channel, 20 min total) were scheduled every hour, for 24 h each day. Each day was divided into three 8-hour shifts. Shift I began at 0600 and ended at 1359; Shift II began at 1400 and ended at 2159 hour; Shift III began at 2200 hour and ended at 0559 hour. The 10-minute count for the west channel began between the top of the hour and the 10-minute count for the east channel began immediately afterwards.

Numbers of Chinook and sockeye salmon were tallied and recorded on data forms at the end of each 10-minute counting period. Separate data forms were maintained for each day and channel. Migration (upstream and downstream) was recorded to provide a net upstream migration during each 10-min count. Migration was defined as passage across the full width of the vinyl panels. In addition, water level (relative level on a staff gauge) and water clarity (Table 1) were recorded each hour before the count. Conditions that might affect the counts (e.g., heavy rain or strong winds) and general observations were recorded in the comments column. Water and air temperature were recorded at the beginning of each shift.

Table 1.–Water clarity classification scheme.

Rank	Description	Salmon Viewing	Water Condition
1	Excellent	All passing salmon are observable	Virtually no turbidity or glare, “drinking water” clarity; all routes of migration observable
2	Good	All passing salmon are observable	Minimal to very low levels of turbidity or glare; all routes of migration observable
3	Fair	All passing salmon are observable	Low to moderate levels of turbidity or glare; all routes of migration observable
4	Poor	Possible, but not likely, that some passing salmon may be missed	Moderate to high levels of turbidity or glare; a few likely routes of migration are partially obscured
4.5 <sup>a</sup>	Very poor	Likely that some passing salmon may be missed	Moderate to high levels of turbidity or glare; some to many likely routes of migration are obscured
5	Unobservable	Passing fish are not observable	High level of turbidity or glare; ALL routes of migration obscured

<sup>a</sup> The ranking of 4.5 was inserted in 2007 to emphasize that further delineation was necessary for defining “poor” visibility. This allows continuity with the scale used in previous years rather than changing the scale to 1–6.

## Data Analysis

Estimates of Chinook salmon escapement were stratified by day. Daily estimates of escapement were a single-stage direct expansion from the 10-min counting periods. The 10-minute counting periods were considered a systematic sample because the counting periods were not chosen randomly. Hourly count data were combined across channels before calculating estimates in order to account for the covariance between channel-specific hourly counts.

An analysis of data collected during 2002 revealed that Chinook salmon had a distinct diel migratory pattern in which the majority of salmon migration took place in the evening and early morning hours (Taras and Sarafin 2005). To account for this pattern of migration, a “count day” was defined as 1600 to 1559. Taras and Sarafin (2005) also demonstrated that interpolating for undercounts (a rank of 4.5 or 5) using this diel migratory pattern yielded more accurate estimates of escapement than using a direct expansion of the successful counts within 8-hour shifts for that day.

The diel pattern is derived from all days with complete counts (no missing hours). A diel pattern consists of 24 proportion estimates, each calculated as the proportion of fish passing through the tower during a given hour period and summed across counting days, out of the total fish count for days with complete counts.

To be reliable, interpolations based on the diel pattern must have at least some counts that were successfully completed during the period of peak migration. Peak migration is defined and estimated as the shortest continuous period of time during a count day that accounted for 80% of the upstream migration of Chinook salmon. Therefore, daily escapement and its variance were estimated using 1 of 3 scenarios depending on water clarity conditions (Table 1):

1. When water clarity was *excellent* to *poor* (rank 1–4) for all scheduled counts during a day, actual counts were expanded to estimate daily escapement (equations 1–3);
2. When a *small portion* (defined below) of a day’s counts were conducted under *very poor* or *unobservable* water clarity (rank 4.5 or 5), daily escapement was estimated using a

combination of expanded actual (equations 1–3) and interpolated (equations 1–4) counts; and

3. When *most or all* of a day's counts were conducted under *very poor* or *unobservable* water clarity (rank 4.5 or 5), escapement for the entire day was interpolated (equations 5–6) using a moving average estimate of daily passage estimates before and after the missing day(s).

**Scenario 1:** For days when all counts were conducted under excellent to poor conditions, daily escapement,  $\hat{N}_d$ , was calculated by expanding counts within a shift for day  $d$  (Cochran 1977):

$$\hat{N}_d = \frac{M_d}{m_d} \sum_{j=1}^{m_d} y_{dj} . \quad (1)$$

The period sampling is systematic, because the sample (or primary unit) has secondary units taken within every hour in a day (i.e., systematically throughout the day). As provided in Wolter (1985), the variance associated with periods was calculated as:

$$s_d^2 = \frac{1}{2(m_d - 1)} \sum_{j=2}^{m_d} (y_{dj} - y_{d(j-1)})^2 . \quad (2)$$

The variance for the expanded daily escapement was estimated as:

$$\hat{V}(\hat{N}_d) = \left(1 - \frac{m_d}{M_d}\right) M_d^2 \frac{s_d^2}{m_d} \quad (3)$$

where:

$d$  = day;

$j$  = paired 10-min counting period (a paired 10-min counting period consists of the two 10-min counts, one per channel, during a given hour);

$y$  = observed period count (both channels combined);

$m$  = number of paired 10-min counting periods sampled; and,

$M$  = total number of possible paired 10-min counting periods.

**Scenario 2:** If counts were conducted successfully for a portion of the day that represented 25% or more of the expected migration for that day (as defined by the diel relationship), and if at least 25% of the periods during peak migration were successfully counted, then the channel-specific interpolated count was calculated as the product of the sum of successful counts for the day and the ratio of the expected daily escapement not represented to the daily escapement that was represented, or:

$$y_{dc,interp} = y_{dc,actual} \times \frac{1 - p_{edp}}{p_{edp}} , \quad (4)$$

where:

$y_{dc,interp}$  = interpolated sum of counts for missing (i.e., very poor or unobservable) 10-min periods by channel;

$y_{dc, \text{actual}}$  = daily sum of successful 10-min counts by channel; and,

$p_{edp}$  = proportion of expected daily escapement successfully counted.

The interpolated count was then allocated among missed 10-min counting periods based on the diel pattern for the current year. For example, if four 10-min counting periods were missed and the interpolated count for that period was 10 Chinook salmon, those 10 fish would be allocated to each of the missed periods in proportion to the diel pattern.

Daily escapement and variances were calculated using a combination of actual and interpolated counts. Treating interpolated counts as “known” would result in underestimating the daily variances. Therefore, daily variance estimates were inflated by decreasing the number of 10-min counting periods,  $m_d$ , sampled each day by the proportion of the expected daily migration successfully counted on that day. For example, if 85% of the expected run was successfully counted on a given day, then the adjusted  $m_d = 0.85 \times m_d = 0.85 \times 24$ . For the channel-combined counts, the proportion successfully counted was the channel-specific proportions weighted by the proportion of the overall run passing each channel. Although inflating the variance calculations guards against a negative bias in estimation of the total variance, this approach could still lead to unacceptably large biases if days with diel interpolations contribute substantially to the overall variance. Therefore, daily variances are estimated using this approach as long as interpolations using the diel pattern account for a small proportion of the total variance.

**Scenario 3:** If counts were conducted for a portion of the day that represented less than 25% of the expected escapement for that day, or if fewer than 25% of the periods during peak migration were counted successfully, then the moving average estimate for the missing day  $i$  was calculated as:

$$\hat{N}_i = \frac{\sum_{j=i-k}^{i+k} I(\text{day } j \text{ was sampled}) \hat{N}_j}{\sum_{j=i-k}^{i+k} I(\text{day } j \text{ was sampled})} \quad (5)$$

where:

$k$  = number of days missed due to adverse viewing conditions; and

$$I(\cdot) = \begin{cases} 1 & \text{when the condition is true} \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

is an indicator function.

The interpolated values were used as the point estimates for the daily counts, and the daily count variance for undercounted days was estimated as the maximum variance of the daily counts out of the  $k$  days before and the  $k$  days after the undercounted day  $i$ .

The season total escapement upstream of the counting tower and its associated variance incorporated all 3 daily migration estimation scenarios (when applicable), and was estimated as (Cochran 1977):

$$\hat{N}_{PT} = \sum_{d=1}^D \hat{N}_d ; \text{ and} \quad (7)$$

$$\hat{V}(\hat{N}_{PT}) = \sum_{d=1}^D \hat{V}(\hat{N}_d), \quad (8)$$

where:

$D$  = total number of possible counting days.

## **SOCKEYE SALMON PARTIAL ESCAPEMENT**

The number of sockeye salmon migrating past the counting tower was estimated using the methods described for estimating Chinook salmon escapement. Because the sockeye salmon run was known to continue after counting ceased each year, the escapement estimate reflects an unknown portion of the total run and should be considered a minimum estimate of escapement.

## **RESULTS**

### **CHINOOK SALMON ESCAPEMENT**

In 2013, the Gulkana River counting tower was in operation from 22 June through 15 August (Table 2). The first Chinook salmon was observed passing the tower on 25 June and the last on 13 August. Very poor water conditions (Table 1) resulted in counts being interpolated for a single partial day (28 June). Total Chinook salmon passage past the counting tower was estimated as 3,936 (SE = 215; 95% CI = 3,515–4,357; Table 3). The 2013 Chinook salmon run was delayed due to a late but rapid breakup. The 25th percentile of cumulative passage did not occur until 21 July, which was the latest on record; however, the 50th percentile was reached just 4 days later and the 75th percentile was reached on 20 July (Figure 4; Table 4). Diel passage was highest during the evening hours with 70% of the run passing the counting tower during the hours of 2200–0700 (Figure 5).

In 2014, the counting tower was in operation from 4 June through 13 August (Table 5). The first Chinook salmon was observed on 5 June and the last one moving upstream was on 9 August. Occluded water resulted in counts being interpolated for the dates 19–22 June and 26 June–6 July, summing to 14 days (11 of which the entire day had to be interpolated). Total Chinook salmon passage past the counting tower was estimated as 3,478 (SE = 271; 95% CI = 2,948–4,009; Table 3). Cumulative run timing indicated the runs arrival was on time, but became delayed after the 25th percentile of passage (relative to that of historic run timing at the tower site; Figure 4; Table 4). The 25th percentile of cumulative passage was reached on 28 June, the 50th percentile was reached on 10 July, and the 75th percentile was reached on 27 July, the latest date on record (Figure 4; Table 4). Diel passage was highest during the evening hours with 89% of the run passing the counting tower during the hours of 2200–0700 (Figure 5).

In 2015, the Gulkana River counting tower was in operation from 2 June through 13 August (Table 6). The first Chinook salmon was observed passing the tower on 9 June and the last was on 10 August. Water conditions remained acceptable for all but a few hourly counts in which interpolation techniques did not call for any adjustments to the recorded counts. Total Chinook salmon passage past the counting tower was estimated as 3,738 (SE = 251; 95% CI = 3,246–4,230; Table 3). Cumulative run timing was similar to historic run timing (Figure 4). The 25th, 50th, and 75th percentiles of cumulative passage were reached on 25 June, 5 July, and 20 July, respectively (Table 4). Diel passage was highest during the evening hours with 83% of the run passing the counting tower during the hours of 2200–0700 (Figure 5).

Table 2.—Daily counts, expanded counts, interpolations, and the cumulative estimated escapement of Chinook salmon at the Gulkana River tower, 2013. Shading identifies days with counts that included interpolation.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	
22-Jun	0	0	0	0	0	0	0	0	0	0
23-Jun	0	0	0	0	0	0	0	0	0	0
24-Jun	0	0	0	0	0	0	0	0	0	0
25-Jun	0	0	0	1	6	6	1	6	6	6
26-Jun	0	0	0	6	26	26	6	36	36	42
27-Jun	6	36	36	14	84	84	20	120	120	162
28-Jun <sup>a</sup>	10	60	60	22	132	180	32	192	240	402
29-Jun	3	18	18	2	12	12	5	30	30	432
30-Jun	2	12	12	1	6	6	3	18	18	450
1-Jul	6	36	36	3	18	18	9	54	54	504
2-Jul	-1	-6	-6	0	0	0	-1	-6	-6	498
3-Jul	0	0	0	2	12	12	2	12	12	510
4-Jul	0	0	0	0	0	0	0	0	0	510
5-Jul	1	6	6	0	0	0	1	6	6	516
6-Jul	0	0	0	0	0	0	0	0	0	516
7-Jul	11	66	66	7	42	42	18	108	108	624
8-Jul	8	48	48	2	12	12	10	60	60	684
9-Jul	14	84	84	4	24	24	18	108	108	792
10-Jul	18	108	108	3	18	18	21	126	126	918
11-Jul	30	180	180	13	78	78	43	258	258	1,176
12-Jul	29	174	174	11	66	66	40	240	240	1,416
13-Jul	36	216	206	30	180	180	66	396	396	1,812
14-Jul	19	114	114	50	300	300	69	414	414	2,226
15-Jul	11	66	66	30	180	180	41	246	246	2,472
16-Jul	4	24	24	28	168	168	32	192	192	2,664
17-Jul	6	36	36	6	36	36	12	72	72	2,736
18-Jul	3	18	18	3	18	18	6	36	36	2,772
19-Jul	18	108	108	4	24	24	22	132	132	2,904
20-Jul	11	66	66	1	6	6	12	72	72	2,976
21-Jul	10	60	60	5	30	30	15	90	90	3,066
22-Jul	6	36	36	1	6	6	7	42	42	3,108
23-Jul	18	108	108	4	24	24	22	132	132	3,240
24-Jul	11	66	66	2	12	12	13	78	78	3,318
25-Jul	4	24	24	9	54	54	13	78	78	3,396
26-Jul	4	24	24	11	66	66	15	90	90	3,486
27-Jul	2	12	12	5	30	30	7	42	42	3,528
28-Jul	2	12	12	2	12	12	4	24	24	3,552
29-Jul	1	6	6	2	12	12	3	18	18	3,570
30-Jul	1	6	6	5	30	30	6	36	36	3,606
31-Jul	1	6	6	13	78	78	14	84	84	3,690
1-Aug	-1	-6	-6	-1	-6	-6	-2	-12	-12	3,678
2-Aug	1	6	6	6	36	36	7	42	42	3,720
3-Aug	1	6	6	-1	-6	-6	0	0	0	3,720
4-Aug	2	12	12	2	12	12	4	24	24	3,744
5-Aug	-1	-6	-6	2	12	12	1	6	6	3,750
6-Aug	2	12	12	6	36	36	8	48	48	3,798
7-Aug	2	12	12	3	18	18	5	30	30	3,828

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Table 2.–Page 2 of 2.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter- polated	Daily	Direct Expanded	Inter- polated	Daily	Direct Expanded	Inter- polated	
8-Aug	-2	-12	-12	1	6	-6	-1	-6	-6	3,822
9-Aug	2	12	12	5	30	42	7	42	42	3,864
10-Aug	2	12	12	0	0	12	2	12	12	3,876
11-Aug	1	6	6	0	0	6	1	6	6	3,882
12-Aug	2	12	12	3	18	30	5	30	30	3,912
13-Aug	2	12	12	2	12	24	4	24	24	3,936
14-Aug	0	0	0	0	0	0	0	0	0	3,936
15-Aug	0	0	0	0	0	0	0	0	0	3,936

<sup>a</sup> Interpolations were from scenario 2.

Table 3.—Estimated escapement of Chinook and sockeye salmon at the Gulkana River tower, 2013–2015.

Year	Dates of Operation	Abundance	SE	95% CI
<u>Chinook Salmon</u>				
2002	7 Jun-9 Aug	6,390	340	5,724-7,056
2003	28 May-17 Aug	4,890	270	4,361-5,419
2004	28 May-14 Aug	4,734	302	4,142-5,326
2005	28 May-15 Aug	2,718	174	2,377-3,059
2006	3 Jun-15 Aug	4,846	279	4,299-5,393
2007	1 Jun-12 Aug	4,442	273	3,907-4,977
2008	31 May-10 Aug	3,678	258	3,172-4,184
2009	31 May-11 Aug	2,720	179	2,369-3,071
2010	31 May-11 Aug	2,267	150	1,973-2,561
2011	2 Jun-10 Aug	3,804	257	3,300-4,308
2012	5 Jun-10 Aug	1,730	157	1,422-2,038
2013	22 Jun-15 Aug	3,936	215	3,515-4,357
2014	4 Jun-13 Aug	3,478	271	2,947-4,009
2015	2 Jun-13 Aug	3,738	251	3,246-4,230
<u>Sockeye Salmon</u>				
2002	7 Jun-9 Aug	30,062	1,472	27,177-32,947
2003	28 May-17 Aug	19,656	800	18,088-21,224
2004	28 May-14 Aug	15,247	633	14,006-16,488
2005	28 May-15 Aug	13,695	539	12,639-14,751
2006	3 Jun-15 Aug	41,919	2,889	36,257-47,581
2007	1 Jun-12 Aug	30,174	1,469	27,295-33,053
2008	31 May-10 Aug	11,400	572	10,279-12,521
2009	31 May-11 Aug	13,088	639	11,836-14,340
2010	31 May-11 Aug	16,255	786	14,714-17,796
2011	2 Jun-10 Aug	38,048	1,683	34,749-41,347
2012	5 Jun-10 Aug	41,953	1,951	38,129-45,777
2013	22 Jun-15 Aug	48,024	1,834	44,429-51,619
2014	4 Jun-13 Aug	27,186	1,236	24,763-29,609
2015	2 Jun-13 Aug	24,624	970	22,723-26,525

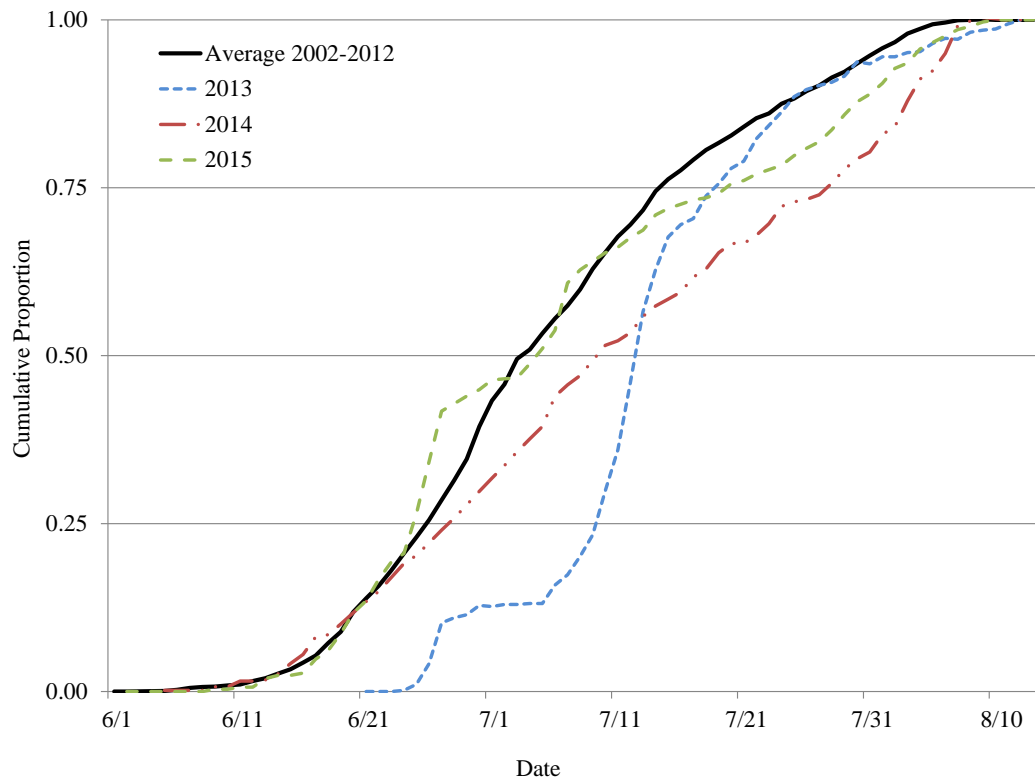


Figure 4.—Estimated run timing pattern for Gulkana River Chinook salmon past the counting tower in 2013–2015, compared to the 2002–2012 average.

Table 4.—Proportion of the cumulative passage of Chinook salmon at the Gulkana River tower, 2002–2015. The dates of 25th, 50th, and 75th percentile are outlined.

Day	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
4-Jun		0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00				0.00
5-Jun		0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
6-Jun		0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
7-Jun	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
8-Jun	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
9-Jun	0.00	0.00	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.00
10-Jun	0.00	0.00	0.05	0.02	0.00	0.00	0.00	0.00	0.02	0.00	0.00		0.01	0.00
11-Jun	0.00	0.00	0.05	0.02	0.00	0.01	0.01	0.00	0.02	0.00	0.00		0.02	0.01
12-Jun	0.00	0.01	0.06	0.04	0.00	0.01	0.01	0.00	0.02	0.00	0.00		0.02	0.01
13-Jun	0.00	0.02	0.06	0.07	0.00	0.01	0.01	0.00	0.02	0.00	0.00		0.02	0.02
14-Jun	0.00	0.03	0.06	0.10	0.01	0.03	0.02	0.00	0.02	0.01	0.01		0.03	0.02
15-Jun	0.00	0.03	0.06	0.13	0.02	0.03	0.03	0.01	0.02	0.01	0.01		0.04	0.02
16-Jun	0.01	0.05	0.07	0.15	0.03	0.04	0.05	0.01	0.03	0.01	0.02		0.06	0.03
17-Jun	0.01	0.06	0.08	0.19	0.03	0.04	0.08	0.01	0.04	0.02	0.03		0.08	0.05
18-Jun	0.03	0.07	0.09	0.30	0.05	0.05	0.11	0.02	0.05	0.02	0.05		0.08	0.06
19-Jun	0.04	0.07	0.13	0.34	0.06	0.06	0.13	0.02	0.07	0.03	0.06		0.10	0.09
20-Jun	0.10	0.08	0.21	0.38	0.07	0.08	0.15	0.03	0.08	0.05	0.07		0.12	0.12
21-Jun	0.14	0.11	0.28	0.38	0.08	0.09	0.17	0.04	0.09	0.06	0.07		0.13	0.14
22-Jun	0.17	0.11	0.35	0.38	0.08	0.10	0.21	0.06	0.12	0.06	0.08	0.00	0.15	0.17
23-Jun	0.18	0.14	0.42	0.41	0.08	0.13	0.22	0.06	0.14	0.07	0.10	0.00	0.17	0.19
24-Jun	0.21	0.16	0.47	0.45	0.10	0.17	0.23	0.07	0.17	0.07	0.16	0.00	0.19	0.21
25-Jun	0.25	0.16	0.55	0.49	0.12	0.19	0.24	0.07	0.18	0.10	0.15	0.00	0.20	0.27
26-Jun	0.27	0.17	0.62	0.50	0.14	0.22	0.25	0.07	0.20	0.18	0.16	0.01	0.22	0.34
27-Jun	0.29	0.17	0.73	0.52	0.16	0.28	0.27	0.07	0.21	0.21	0.16	0.04	0.24	0.42
28-Jun	0.35	0.17	0.81	0.53	0.18	0.34	0.29	0.08	0.23	0.21	0.16	0.10	0.26	0.43
29-Jun	0.38	0.28	0.82	0.55	0.21	0.41	0.29	0.09	0.24	0.21	0.17	0.11	0.28	0.44
30-Jun	0.49	0.37	0.83	0.60	0.28	0.45	0.30	0.11	0.26	0.22	0.18	0.11	0.30	0.45
1-Jul	0.54	0.51	0.83	0.63	0.30	0.47	0.32	0.12	0.28	0.23	0.19	0.13	0.32	0.46
2-Jul	0.55	0.60	0.83	0.66	0.33	0.50	0.33	0.14	0.29	0.23	0.20	0.13	0.34	0.47
3-Jul	0.61	0.61	0.84	0.68	0.36	0.52	0.37	0.18	0.35	0.33	0.23	0.13	0.36	0.47
4-Jul	0.61	0.61	0.84	0.70	0.37	0.53	0.39	0.21	0.37	0.34	0.23	0.13	0.38	0.49
5-Jul	0.62	0.64	0.85	0.72	0.42	0.55	0.47	0.23	0.38	0.35	0.25	0.13	0.39	0.51
6-Jul	0.63	0.66	0.85	0.72	0.44	0.56	0.53	0.33	0.39	0.35	0.26	0.13	0.44	0.54
7-Jul	0.64	0.69	0.85	0.74	0.46	0.57	0.55	0.40	0.40	0.38	0.28	0.16	0.46	0.61
8-Jul	0.66	0.69	0.85	0.74	0.51	0.57	0.58	0.52	0.42	0.42	0.30	0.17	0.47	0.63
9-Jul	0.70	0.71	0.85	0.75	0.52	0.58	0.62	0.62	0.44	0.51	0.31	0.20	0.49	0.64
10-Jul	0.73	0.74	0.86	0.77	0.54	0.59	0.66	0.75	0.47	0.53	0.31	0.23	0.52	0.65
11-Jul	0.76	0.78	0.86	0.78	0.57	0.59	0.68	0.79	0.50	0.54	0.32	0.30	0.52	0.66
12-Jul	0.77	0.80	0.86	0.78	0.62	0.60	0.69	0.84	0.52	0.58	0.35	0.36	0.53	0.68
13-Jul	0.78	0.82	0.87	0.80	0.66	0.61	0.71	0.89	0.52	0.58	0.36	0.46	0.56	0.69
14-Jul	0.81	0.84	0.89	0.81	0.73	0.65	0.73	0.92	0.52	0.62	0.37	0.57	0.57	0.71
15-Jul	0.82	0.86	0.89	0.81	0.75	0.69	0.74	0.94	0.53	0.62	0.38	0.63	0.58	0.72
16-Jul	0.84	0.87	0.90	0.83	0.76	0.74	0.76	0.95	0.54	0.62	0.39	0.68	0.59	0.73
17-Jul	0.87	0.88	0.90	0.84	0.76	0.77	0.76	0.96	0.58	0.63	0.39	0.70	0.62	0.73
18-Jul	0.89	0.88	0.90	0.84	0.78	0.81	0.77	0.96	0.63	0.63	0.39	0.70	0.63	0.74
19-Jul	0.90	0.89	0.90	0.85	0.79	0.84	0.78	0.96	0.69	0.64	0.43	0.74	0.65	0.74
20-Jul	0.91	0.89	0.90	0.86	0.80	0.87	0.79	0.97	0.71	0.64	0.45	0.76	0.67	0.76
21-Jul	0.92	0.89	0.91	0.86	0.80	0.88	0.79	0.97	0.75	0.67	0.55	0.78	0.67	0.76
22-Jul	0.93	0.90	0.91	0.87	0.81	0.91	0.80	0.97	0.79	0.68	0.57	0.79	0.68	0.77
23-Jul	0.94	0.90	0.91	0.88	0.81	0.92	0.80	0.97	0.82	0.70	0.59	0.82	0.70	0.78

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Table 4.–Page 2 of 2.

Day	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
23-Jul	0.94	0.90	0.91	0.89	0.84	0.93	0.80	0.97	0.85	0.75	0.60	0.84	0.72	0.78
24-Jul	0.95	0.90	0.91	0.90	0.85	0.95	0.83	0.97	0.87	0.76	0.65	0.86	0.73	0.80
25-Jul	0.95	0.90	0.90	0.91	0.86	0.96	0.87	0.97	0.89	0.77	0.74	0.89	0.73	0.81
26-Jul	0.95	0.90	0.90	0.91	0.87	0.96	0.88	0.98	0.89	0.78	0.80	0.90	0.74	0.82
27-Jul	0.95	0.91	0.90	0.94	0.88	0.97	0.89	0.98	0.91	0.80	0.88	0.90	0.76	0.85
28-Jul	0.95	0.90	0.90	0.94	0.90	0.97	0.91	0.98	0.92	0.83	0.91	0.91	0.78	0.86
29-Jul	0.95	0.92	0.92	0.95	0.91	0.98	0.93	0.98	0.93	0.86	0.94	0.92	0.79	0.88
30-Jul	0.96	0.93	0.94	0.96	0.94	0.98	0.94	0.99	0.93	0.90	0.95	0.94	0.80	0.89
31-Jul	0.96	0.95	0.95	0.96	0.94	0.98	0.95	0.99	0.95	0.94	0.98	0.93	0.83	0.91
1-Aug	0.97	0.95	0.96	0.97	0.95	0.98	0.97	0.99	0.97	0.95	0.99	0.95	0.84	0.92
2-Aug	0.98	0.96	0.98	0.98	0.97	0.99	0.97	0.99	0.97	0.99	1.00	0.95	0.88	0.94
3-Aug	0.98	0.97	1.00	0.99	0.97	0.99	1.00	1.00	0.97	1.00	1.00	0.95	0.91	0.96
4-Aug	0.98	0.98	0.99	1.00	0.99	1.00	1.00	1.00	0.99	1.00	1.00	0.95	0.92	0.97
5-Aug	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.95	0.98
6-Aug	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.99	0.99
7-Aug	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00	0.99
8-Aug	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00
9-Aug	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00
10-Aug	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00
11-Aug	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00
12-Aug	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13-Aug	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14-Aug	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15-Aug	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

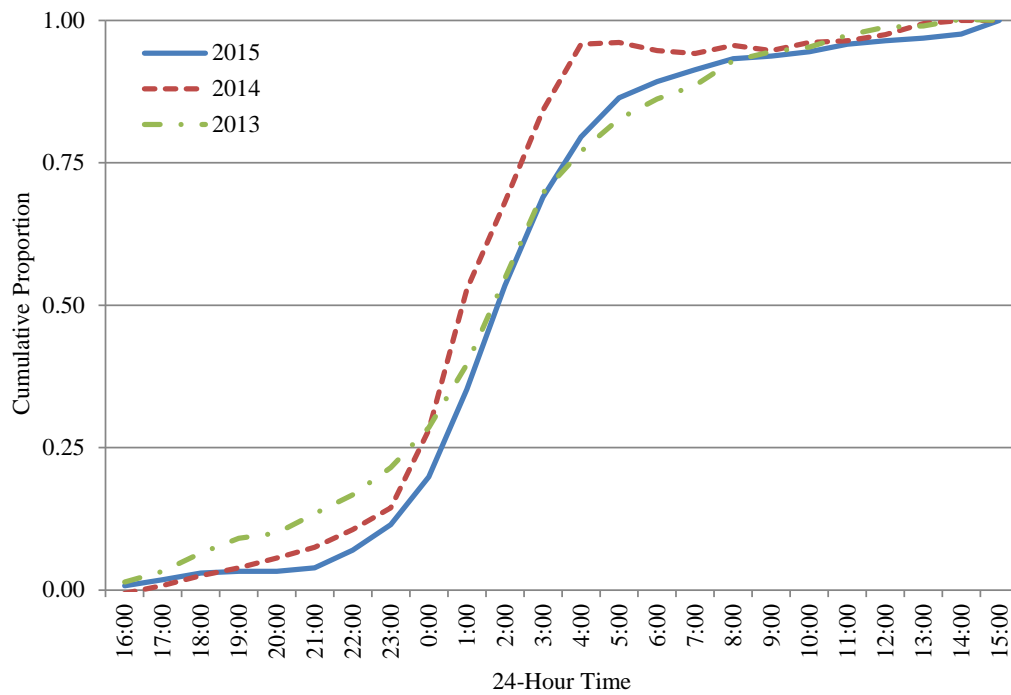


Figure 5.—Estimated diel migratory pattern for 2013–2015, the cumulative proportion of average daily counts by hour of day for Chinook salmon migrating past the Gulkana River counting tower.

Table 5.—Daily counts, expanded counts, interpolations, and the cumulative estimated escapement of Chinook salmon at the Gulkana River tower, 2014. Shading identifies days with counts that included interpolation.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	
4-Jun	0	0	0	0	0	0	0	0	0	0
5-Jun	0	0	0	1	6	6	1	6	6	6
6-Jun	0	0	0	0	0	0	0	0	0	6
7-Jun	0	0	0	0	0	0	0	0	0	6
8-Jun	0	0	0	0	0	0	0	0	0	6
9-Jun	3	18	18	0	0	0	3	18	18	24
10-Jun	0	0	0	0	0	0	0	0	0	24
11-Jun	5	30	30	0	0	0	5	30	30	54
12-Jun	0	0	0	0	0	0	0	0	0	54
13-Jun	0	0	0	1	6	6	1	6	6	60
14-Jun	0	0	0	5	30	30	5	30	30	90
15-Jun	2	12	12	7	42	42	9	54	54	144
16-Jun	2	12	12	6	36	36	8	48	48	192
17-Jun	3	18	18	12	72	72	15	90	90	282
18-Jun	1	6	6	1	6	6	2	12	12	294
19-Jun <sup>b</sup>	0	0	10	0	0	46	0	0	56	350
20-Jun <sup>b</sup>	0	0	9	0	0	50	0	0	59	409
21-Jun <sup>b</sup>	0	0	10	0	0	48	0	0	58	467
22-Jun <sup>b</sup>	0	0	10	0	0	43	0	0	53	520
23-Jun	0	0	0	12	72	72	12	72	72	592
24-Jun	1	6	6	11	66	66	12	72	72	664
25-Jun	3	18	18	4	24	24	7	42	42	706
26-Jun <sup>b</sup>	0	0	17	0	0	48	0	0	65	771
27-Jun <sup>b</sup>	0	0	22	0	0	44	0	0	66	837
28-Jun <sup>b</sup>	0	0	21	0	0	41	0	0	62	899
29-Jun <sup>b</sup>	0	0	28	0	0	40	0	0	68	967
30-Jun <sup>b</sup>	2	12	33	0	0	37	2	12	70	1,037
1-Jul <sup>b</sup>	3	18	33	0	0	34	3	18	67	1,104
2-Jul <sup>b</sup>	0	0	34	0	0	32	0	0	66	1,170
3-Jul <sup>b</sup>	0	0	35	0	0	36	0	0	71	1,241
4-Jul <sup>b</sup>	0	0	35	0	0	32	0	0	67	1,308
5-Jul <sup>b</sup>	0	0	35	0	0	29	0	0	64	1,372
6-Jul <sup>a</sup>	17	102	102	10	60	54	27	162	156	1,528
7-Jul	9	54	54	1	6	6	10	60	60	1,588
8-Jul	3	18	18	5	30	30	8	48	48	1,636
9-Jul	13	78	78	0	0	0	13	78	78	1,714
10-Jul	11	66	66	2	12	12	13	78	78	1,792
11-Jul	1	6	6	3	18	18	4	24	24	1,816
12-Jul	3	18	18	4	24	24	7	42	42	1,858
13-Jul	2	12	12	12	72	72	14	84	84	1,942
14-Jul	2	12	12	7	42	42	9	54	54	1,996
15-Jul	1	6	6	5	30	30	6	36	36	2,032
16-Jul	2	12	12	4	24	24	6	36	36	2,068
17-Jul	6	36	36	7	42	42	13	78	78	2,146
18-Jul	7	42	42	0	0	0	7	42	42	2,188
19-Jul	12	72	72	2	12	12	14	84	84	2,272
20-Jul	6	36	36	2	12	12	8	48	48	2,320

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Table 5.–Page 2 of 2.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	
21-Jul	2	12	12	-2	-12	-12	0	0	0	2,320
22-Jul	7	42	42	0	0	0	7	42	42	2,362
23-Jul	10	60	60	0	0	0	10	60	60	2,422
24-Jul	17	102	102	-2	-12	-12	15	90	90	2,512
25-Jul	2	12	12	2	12	12	4	24	24	2,536
26-Jul	0	0	0	2	12	12	2	12	12	2,548
27-Jul	0	0	0	4	24	24	4	24	24	2,572
28-Jul	4	24	24	6	36	36	10	60	60	2,632
29-Jul	6	36	36	6	36	36	12	72	72	2,704
30-Jul	0	0	0	9	54	54	9	54	54	2,758
31-Jul	4	24	24	2	12	12	6	36	36	2,794
1-Aug	6	36	36	9	54	54	15	90	90	2,884
2-Aug	7	42	42	0	0	0	7	42	42	2,926
3-Aug	14	84	84	8	48	48	22	132	132	3,058
4-Aug	18	108	108	1	6	6	19	114	114	3,172
5-Aug	7	42	42	0	0	0	7	42	42	3,214
6-Aug	14	84	84	1	6	6	15	90	90	3,304
7-Aug	24	144	144	0	0	0	24	144	144	3,448
8-Aug	4	24	24	0	0	0	4	24	24	3,472
9-Aug	3	18	18	0	0	0	3	18	18	3,490
10-Aug	0	0	0	-1	-6	-6	-1	-6	-6	3,484
11-Aug	-1	-6	-6	0	0	0	-1	-6	-6	3,478
12-Aug	0	0	0	0	0	0	0	0	0	3,478
13-Aug	0	0	0	0	0	0	0	0	0	3,478

<sup>a</sup> Interpolations were from scenario 2.<sup>b</sup> Interpolations were from scenario 3.

## SOCKEYE SALMON PARTIAL ESCAPEMENT

In 2013, an estimated 48,024 (SE = 1,834; 95% CI = 44,429–51,619) sockeye salmon passed the counting tower during its operational time period (Tables 3 and 7), and was the highest count on record. The 2014 estimate of sockeye salmon passage was 27,186 (SE = 1,236; 95% CI = 24,764–29,609; Tables 3 and 8). In 2015, an estimated 24,624 (SE = 970; 95% CI = 22,722–26,526) sockeye salmon passed the counting tower (Tables 3 and 9). Interpolations were done on the same dates listed above for Chinook salmon. The exception was in 2015 when the few hours of very poor water conditions (Table 1) had an interpolated expanded count of 6 sockeye salmon added for that day (Table 9).

## DISCUSSION

Estimates within the relative precision (RP) criteria of the objectives were attained in 2013 (RP = 0.11), 2014 (RP = 0.15) and 2015 (0.13). All 3 estimates represent the entire Chinook salmon escapement above the counting tower. The estimated Chinook salmon passage from 2013 through 2015 was consistent, varying by <500 fish among years. These 3 years collectively show an improvement of Chinook salmon escapement over the previous 5 years (Figure 6), but still below 5 of the first 6 years of the tower's operation.

Since angling opportunity exists for Chinook salmon above the counting tower, the tower counts sometimes may not represent true escapement numbers. Harvest above the counting tower has been estimated since 2007 and has averaged 91 fish from 2007 through 2014<sup>1</sup>. Restrictions to the sport fishery occurred in 2013 and 2014 resulting in zero Chinook salmon being harvested above the counting tower. Data from 2015 was not available at the time of publication, though no fishery restrictions were imposed that year.

Despite the Gulkana River counting tower not becoming operational until 22 June in 2013 due to high water, it is believed that the entire Chinook salmon run was enumerated. The spring of 2013 was unusual with an extremely late but rapid breakup occurring. Freshwater migration of salmon at the ADF&G operated Miles Lake sonar site was over a week late due to heavy ice in the river until mid-May (Sheridan et al. 2013). The late breakup was rapid, causing both the Copper and Gulkana rivers to run extremely high from late May through mid-June, both of which probably reduced migrating salmon swim speeds as well. No Chinook salmon were counted the first 2 days of the tower's operation, and only a single Chinook salmon was counted on the third day. Furthermore, an ADF&G crew radiotagging Chinook salmon at the mouth of the Gulkana River did not capture their first Chinook salmon until 21 June 2013 (Schwanke *In prep*).

The partial sockeye escapement was the highest ever in 2013 but then dropped to near historic means in 2014 and 2015 (Figure 7). As with Chinook salmon, it is believed that very few sockeye salmon were missed in 2013 with the late start-up date for the counting tower. Zero sockeye salmon were counted during the first day of operation and 18 on the second day (Table 7).

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<sup>1</sup> Alaska Sport Fishing Survey database [Internet]. 1996– . Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish (cited October 8, 2015). Available from: <http://www.adfg.alaska.gov/sf/sportfishingsurvey/>

Table 6.—Daily counts, expanded counts, and the cumulative estimated escapement of Chinook salmon at the Gulkana River tower, 2015.

Date	West Channel		East Channel		Combined		Total Escapement
	Daily	Expanded	Daily	Expanded	Daily	Expanded	
2-Jun	0	0	0	0	0	0	0
3-Jun	0	0	0	0	0	0	0
4-Jun	0	0	0	0	0	0	0
5-Jun	0	0	0	0	0	0	0
6-Jun	0	0	0	0	0	0	0
7-Jun	0	0	0	0	0	0	0
8-Jun	0	0	0	0	0	0	0
9-Jun	0	0	2	12	2	12	12
10-Jun	0	0	0	0	0	0	12
11-Jun	1	6	1	6	2	12	24
12-Jun	0	0	0	0	0	0	24
13-Jun	8	48	0	0	8	48	72
14-Jun	3	18	0	0	3	18	90
15-Jun	0	0	0	0	0	0	90
16-Jun	2	12	0	0	2	12	102
17-Jun	7	42	6	36	13	78	180
18-Jun	7	42	1	6	8	48	228
19-Jun	11	66	5	30	16	96	324
20-Jun	13	78	6	36	19	114	438
21-Jun	12	72	-1	-6	11	66	504
22-Jun	18	108	2	12	20	120	624
23-Jun	11	66	5	30	16	96	720
24-Jun	6	36	2	12	8	48	768
25-Jun	29	174	8	48	37	222	990
26-Jun	27	162	21	126	48	288	1,278
27-Jun	31	186	16	96	47	282	1,560
28-Jun	2	12	5	30	7	42	1,602
29-Jun	6	36	1	6	7	42	1,644
30-Jun	3	18	3	18	6	36	1,680
1-Jul	10	60	-1	-6	9	54	1,734
2-Jul	0	0	1	6	1	6	1,740
3-Jul	0	0	1	6	1	6	1,746
4-Jul	3	18	10	60	13	78	1,824
5-Jul	7	42	7	42	14	84	1,908
6-Jul	12	72	5	30	17	102	2,010
7-Jul	13	78	31	186	44	264	2,274
8-Jul	3	18	9	54	12	72	2,346
9-Jul	1	6	7	42	8	48	2,394
10-Jul	1	6	7	42	8	48	2,442
11-Jul	2	12	3	18	5	30	2,472
12-Jul	2	12	7	42	9	54	2,526
13-Jul	5	30	2	12	7	42	2,568
14-Jul	10	60	4	24	14	84	2,652
15-Jul	3	18	3	18	6	36	2,688

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Table 6.–Page 2 of 2.

Date	West Channel		East Channel		Combined		Total Escapement
	Daily	Expanded	Daily	Expanded	Daily	Expanded	
16-Jul	4	24	0	0	4	24	2,712
17-Jul	4	24	0	0	4	24	2,736
18-Jul	1	6	1	6	2	12	2,748
19-Jul	2	12	2	12	4	24	2,772
20-Jul	5	30	4	24	9	54	2,826
21-Jul	0	0	3	18	3	18	2,844
22-Jul	4	24	2	12	6	36	2,880
23-Jul	3	18	1	6	4	24	2,904
24-Jul	3	18	1	6	4	24	2,928
25-Jul	6	36	3	18	9	54	2,982
26-Jul	4	24	3	18	7	42	3,024
27-Jul	4	24	2	12	6	36	3,060
28-Jul	8	48	3	18	11	66	3,126
29-Jul	8	48	6	36	14	84	3,210
30-Jul	9	54	3	18	12	72	3,282
31-Jul	4	24	3	18	7	42	3,324
1-Aug	7	42	3	18	10	60	3,384
2-Aug	8	48	6	36	14	84	3,468
3-Aug	0	0	5	30	5	30	3,498
4-Aug	7	42	6	36	13	78	3,576
5-Aug	3	18	3	18	6	36	3,612
6-Aug	3	18	3	18	6	36	3,648
7-Aug	3	18	3	18	6	36	3,684
8-Aug	1	6	2	12	3	18	3,702
9-Aug	3	18	1	6	4	24	3,726
10-Aug	2	12	0	0	2	12	3,738
11-Aug	0	0	0	0	0	0	3,738
12-Aug	0	0	0	0	0	0	3,738
13-Aug	0	0	0	0	0	0	3,738

Table 7.—Daily counts, expanded counts, and the cumulative estimated escapement of sockeye salmon at the Gulkana River tower, 2013. Shading identifies days with counts that included interpolation.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	
22-Jun	0	0	0	0	0	0	0	0	0	0
23-Jun	1	6	6	2	12	12	3	18	18	18
24-Jun	3	18	18	24	144	144	27	162	162	180
25-Jun	8	48	48	11	66	66	19	114	114	394
26-Jun	24	144	144	39	234	234	63	378	378	672
27-Jun	19	114	114	40	240	240	59	354	354	1,026
28-Jun <sup>a</sup>	34	204	204	68	408	462	102	612	666	1,692
29-Jun	13	78	78	24	144	144	37	222	222	1,914
30-Jun	8	48	48	40	240	240	48	288	288	2,202
1-Jul	13	78	78	20	120	120	33	198	198	2,400
2-Jul	9	54	54	37	222	222	46	276	276	2,676
3-Jul	5	30	30	12	72	72	17	102	102	2,778
4-Jul	4	24	24	7	42	42	11	66	66	2,844
5-Jul	-1	-6	-6	19	114	114	18	108	108	2,952
6-Jul	2	12	12	4	24	24	6	36	36	2,988
7-Jul	8	48	48	11	66	66	19	114	114	3,102
8-Jul	21	126	126	62	372	372	83	498	498	3,600
9-Jul	20	120	120	108	648	648	128	768	768	4,368
10-Jul	72	432	432	237	1,422	1,422	309	1,854	1,854	6,222
11-Jul	34	204	204	497	2,982	2,982	531	3,186	3,186	9,408
12-Jul	100	600	600	414	2,484	2,484	514	3,084	3,084	12,492
13-Jul	212	1,272	1,272	289	1,734	1,734	501	3,006	3,006	15,498
14-Jul	75	450	450	191	1,146	1,146	266	1,596	1,596	17,094
15-Jul	92	552	552	177	1,062	1,062	269	1,614	1,614	18,708
16-Jul	107	642	642	177	1,062	1,062	284	1,704	1,704	20,412
17-Jul	158	948	948	96	576	576	254	1,524	1,524	21,936
18-Jul	118	708	708	271	1,626	1,626	389	2,334	2,334	24,270
19-Jul	177	1,062	1,062	242	1,452	1,452	419	2,514	2,514	26,874
20-Jul	213	1,278	1,278	180	1,080	1,080	393	2,358	2,358	29,142
21-Jul	141	846	846	57	342	342	198	1,188	1,188	30,330
22-Jul	180	1,080	1,080	45	270	270	225	1,350	1,350	31,680
23-Jul	206	1,236	1,236	84	504	504	290	1,740	1,740	33,420
24-Jul	177	1,062	1,062	85	510	510	262	1,572	1,572	34,992
25-Jul	157	942	942	44	264	264	201	1,206	1,206	36,198
26-Jul	135	810	810	25	150	150	160	960	960	37,158
27-Jul	164	984	984	79	474	474	243	1,458	1,458	38,616
28-Jul	258	1,548	1,548	106	636	636	364	2,184	2,184	40,800
29-Jul	178	1,098	1,098	86	516	516	264	1,584	1,584	42,684
30-Jul	82	492	492	72	432	432	154	924	924	43,308
31-Jul	53	318	318	34	204	204	87	522	522	43,830
1-Aug	58	348	348	26	156	156	84	504	504	44,334
2-Aug	75	450	450	72	432	432	147	882	882	45,216
3-Aug	39	234	234	17	102	102	56	336	336	45,552
4-Aug	10	60	60	5	30	30	15	90	90	45,642
5-Aug	5	30	30	6	36	36	11	66	66	45,708
6-Aug	7	42	42	16	96	96	23	138	138	45,846
7-Aug	2	12	12	3	18	18	5	30	30	45,876

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Table 7.–Page 2 of 2

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter- polated	Daily	Direct Expanded	Inter- polated	Daily	Direct Expanded	Inter- polated	
8-Aug	1	6	6	2	12	12	3	18	18	45,894
9-Aug	0	0	0	1	6	6	1	6	6	45,900
10-Aug	2	12	12	10	60	60	12	72	72	45,972
11-Aug	4	24	24	-1	-6	-6	3	18	18	45,990
12-Aug	51	306	306	23	138	138	74	444	444	46,434
13-Aug	61	366	366	41	246	246	102	612	612	47,046
14-Aug	42	252	252	19	114	114	61	366	366	47,414
15-Aug	66	396	396	36	216	216	102	612	612	48,024

<sup>a</sup> Interpolations were from scenario 2.

Table 8.—Daily counts, expanded counts, interpolations, and the cumulative estimated escapement of sockeye salmon at the Gulkana River tower, 2014. Shading identifies days with counts that included interpolation.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	
4-Jun	0	0	0	4	4	4	4	4	4	4
5-Jun	36	216	216	41	246	246	77	462	462	466
6-Jun	45	270	270	46	276	276	91	546	546	1,012
7-Jun	29	174	174	40	240	240	69	414	414	1,426
8-Jun	38	228	228	22	132	132	60	360	360	1,786
9-Jun	48	288	288	4	24	24	52	312	312	2,098
10-Jun	89	534	534	27	162	162	116	696	696	2,794
11-Jun	63	378	378	55	330	330	118	708	708	3,502
12-Jun	32	192	192	42	252	252	74	444	444	3,946
13-Jun	107	642	642	81	486	486	188	1128	1128	5,074
14-Jun	61	366	366	93	558	558	154	924	924	5,998
15-Jun	39	264	264	72	432	432	111	666	666	6,664
16-Jun	44	264	264	65	390	390	109	654	654	7,318
17-Jun	59	354	354	101	606	606	160	960	960	8,278
18-Jun	10	60	60	13	78	78	23	138	138	8,416
19-Jun <sup>b</sup>	0	0	182	0	0	330	0	0	512	8,928
20-Jun <sup>b</sup>	0	0	146	0	0	293	0	0	439	9,367
21-Jun <sup>b</sup>	0	0	109	0	0	255	0	0	364	9,731
22-Jun <sup>b</sup>	0	0	63	0	0	190	0	0	253	9,984
23-Jun <sup>a</sup>	0	0	0	24	144	144	24	144	144	10,128
24-Jun	9	54	54	41	246	246	50	300	300	10,428
25-Jun	13	78	78	33	198	198	46	276	276	10,704
26-Jun <sup>b</sup>	0	0	127	0	0	283	0	0	410	11,114
27-Jun <sup>b</sup>	0	0	107	0	0	255	0	0	362	11,476
28-Jun <sup>b</sup>	0	0	80	0	0	229	0	0	309	11,785
29-Jun <sup>b</sup>	0	0	77	0	0	235	0	0	312	12,097
30-Jun <sup>b</sup>	0	0	60	0	0	225	0	0	285	12,382
1-Jul <sup>b</sup>	2	12	54	17	102	203	19	114	257	12,639
2-Jul <sup>b</sup>	0	0	53	0	0	193	0	0	246	12,885
3-Jul <sup>b</sup>	0	0	51	0	0	203	0	0	254	13,139
4-Jul <sup>b</sup>	0	0	51	0	0	206	0	0	257	13,396
5-Jul <sup>b</sup>	0	0	53	8	48	207	8	48	260	13,656
6-Jul <sup>a</sup>	13	78	78	48	288	384	61	366	462	14,118
7-Jul	7	42	42	15	90	90	22	132	132	14,250
8-Jul <sup>a</sup>	9	54	54	54	348	324	63	402	378	14,628
9-Jul	3	18	18	26	156	156	29	174	174	14,802
10-Jul	7	42	42	28	168	168	35	210	210	15,012
11-Jul	13	78	78	10	60	60	23	138	138	15,150
12-Jul	17	102	102	23	138	138	40	240	240	15,390
13-Jul	6	36	36	51	306	306	57	342	342	15,732
14-Jul	0	0	0	29	174	174	29	174	174	15,906
15-Jul	13	78	78	42	252	252	55	330	330	16,236
16-Jul	23	138	138	26	156	156	49	294	294	16,530
17-Jul	19	114	114	45	270	270	64	384	384	16,914
18-Jul	6	36	36	28	168	168	34	204	204	17,118
19-Jul	15	90	90	14	84	84	29	174	174	17,292
20-Jul	6	36	36	4	24	24	10	60	60	17,352
21-Jul	0	0	0	7	42	42	7	42	42	17,394
22-Jul	9	54	54	18	108	108	27	162	162	17,556
23-Jul	8	48	48	5	30	30	13	78	78	17,634

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Table 8.–Page 2 of 2.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	
24-Jul	2	12	12	9	54	54	11	66	66	17,700
25-Jul	11	66	66	20	120	120	31	186	186	17,886
26-Jul	5	30	30	13	78	78	18	108	108	17,994
27-Jul	7	42	42	6	36	36	13	78	78	18,072
28-Jul	11	66	66	16	96	96	27	162	162	18,234
29-Jul	9	54	54	16	96	96	25	150	150	18,384
30-Jul	9	54	54	19	114	114	28	168	168	18,552
31-Jul	7	42	42	15	90	90	22	132	132	18,684
1-Aug	9	54	54	46	276	276	55	330	330	19,014
2-Aug	7	42	42	37	222	222	44	264	264	19,278
3-Aug	17	102	102	53	318	318	70	420	420	19,698
4-Aug	19	114	114	64	384	384	83	498	498	20,196
5-Aug	15	90	90	52	312	312	67	402	402	20,598
6-Aug	14	84	84	103	618	618	117	702	702	21,300
7-Aug	8	48	48	109	654	654	117	702	702	22,002
8-Aug	33	198	198	118	708	708	151	906	906	22,908
9-Aug	34	204	204	57	342	342	91	546	546	23,454
10-Aug	36	216	216	88	528	528	124	744	744	24,198
11-Aug	112	672	672	188	1,128	1,128	300	1,800	1,800	25,998
12-Aug	72	432	432	66	396	396	138	828	828	26,826
13-Aug	12	72	72	8	48	48	20	120	120	27,186

<sup>a</sup> Interpolations were from scenario 2.<sup>b</sup> Interpolations were from scenario 3.

Table 9.—Daily counts, expanded counts, interpolations, and the cumulative estimated escapement of sockeye salmon at the Gulkana River tower, 2015. Shading identifies days with counts that included interpolation.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	
2-Jun	0	0	0	4	24	24	4	24	24	24
3-Jun	0	0	0	5	30	30	5	30	30	54
4-Jun	1	6	6	9	54	54	10	60	60	114
5-Jun	-1	-6	-6	7	42	42	6	36	36	450
6-Jun	-1	-6	-6	10	60	60	9	54	54	204
7-Jun	7	42	42	33	198	198	40	240	240	444
8-Jun	23	138	138	32	192	192	55	330	330	774
9-Jun	60	360	360	65	390	390	125	750	750	1,524
10-Jun	54	324	324	8	48	48	62	372	372	1,896
11-Jun	53	318	318	22	132	132	75	450	450	2,346
12-Jun	55	330	330	15	90	90	70	420	420	2,766
13-Jun	66	396	396	9	54	54	75	450	450	3,216
14-Jun	156	936	936	17	102	102	173	1038	1038	4,254
15-Jun	193	1158	1158	54	324	324	247	1482	1482	5,736
16-Jun	133	798	798	29	174	174	132	972	972	6,708
17-Jun	168	1008	1008	75	450	450	243	1458	1458	8,166
18-Jun	133	798	798	56	336	336	189	1134	1134	9,300
19-Jun	126	756	756	44	264	264	170	1020	1020	10,320
20-Jun	89	534	534	24	144	144	113	678	678	10,998
21-Jun	112	672	672	21	126	126	133	798	798	11,796
22-Jun	78	468	468	33	198	198	111	666	666	12,462
23-Jun	63	378	378	31	186	186	94	564	564	13,026
24-Jun	63	38	38	9	54	54	72	432	432	13,458
25-Jun	80	480	480	31	186	186	111	666	666	14,124
26-Jun	79	474	474	47	282	282	126	756	756	14,880
27-Jun	79	474	474	43	258	258	122	732	732	15,612
28-Jun	59	354	354	12	72	72	71	426	426	16,038
29-Jun	31	186	186	26	156	156	57	342	342	16,380
30-Jun	55	330	330	8	48	48	63	378	378	16,758
1-Jul	33	198	198	6	36	36	39	234	234	16,992
2-Jul	3	18	18	11	66	66	14	84	84	17,076
3-Jul	22	132	132	20	120	120	42	252	252	17,328
4-Jul	78	468	468	15	90	90	93	558	558	17,886
5-Jul	9	54	54	18	108	108	27	162	162	18,048
6-Jul	17	102	102	28	168	168	45	270	270	18,318
7-Jul	16	96	96	26	156	156	42	252	252	18,570
8-Jul	12	72	72	9	54	54	21	126	126	18,696
9-Jul	7	42	42	9	54	54	16	96	96	18,792
10-Jul	22	132	132	29	174	174	51	306	306	19,098
11-Jul	10	60	60	16	96	96	26	156	156	19,254
12-Jul	5	30	30	11	66	66	16	96	96	19,350
13-Jul	3	18	18	11	66	66	14	84	84	19,434
14-Jul	5	30	30	4	24	24	9	54	54	19,488
15-Jul	19	114	114	7	42	42	26	156	156	19,644
16-Jul <sup>a</sup>	16	96	102	25	150	150	41	246	252	19,896
17-Jul	16	96	96	67	402	402	83	498	498	20,394
18-Jul	8	48	48	16	96	96	24	144	144	20,538
19-Jul	18	108	108	27	162	162	45	270	270	20,808
20-Jul	13	78	78	13	78	78	26	156	156	20,964

-continued-

Table 9.–Page 2 of 2.

Date	West Channel			East Channel			Combined			Total Escapement
	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	Daily	Direct Expanded	Inter-polated	
21-Jul	7	42	42	0	0	0	7	42	42	21,006
22-Jul	11	66	66	11	66	66	22	132	132	21,138
23-Jul	25	150	150	1	6	6	26	156	156	21,294
24-Jul	21	126	126	1	90	90	36	216	216	21,510
25-Jul	17	102	102	26	156	156	43	258	258	21,768
26-Jul	10	60	60	12	72	72	22	132	132	21,900
27-Jul	3	18	18	1	6	6	4	24	24	21,924
28-Jul	9	54	54	6	36	36	15	90	90	22,014
29-Jul	4	24	24	2	12	12	6	36	36	22,050
30-Jul	5	30	30	15	90	90	20	120	120	22,170
31-Jul	4	24	24	6	36	36	10	60	60	22,230
1-Aug	4	24	24	9	54	54	13	78	78	22,308
2-Aug	5	30	30	8	48	48	13	78	78	22,386
3-Aug	10	60	60	11	66	66	21	126	126	22,512
4-Aug	20	120	120	9	54	54	29	174	174	22,686
5-Aug	25	150	150	102	612	612	127	762	762	23,448
6-Aug	4	24	24	5	30	30	9	54	54	23,502
7-Aug	7	42	42	6	36	36	13	78	78	23,580
8-Aug	32	192	192	14	84	84	46	276	276	23,856
9-Aug	47	282	282	20	120	120	67	402	402	24,258
10-Aug	9	54	54	6	36	36	15	90	90	24,348
11-Aug	15	90	90	7	42	42	22	132	132	24,480
12-Aug	8	48	48	16	96	96	24	144	144	24,624
13-Aug	0	0	0	0	0	0	0	0	0	24,624

<sup>a</sup> Interpolations were from scenario 2.

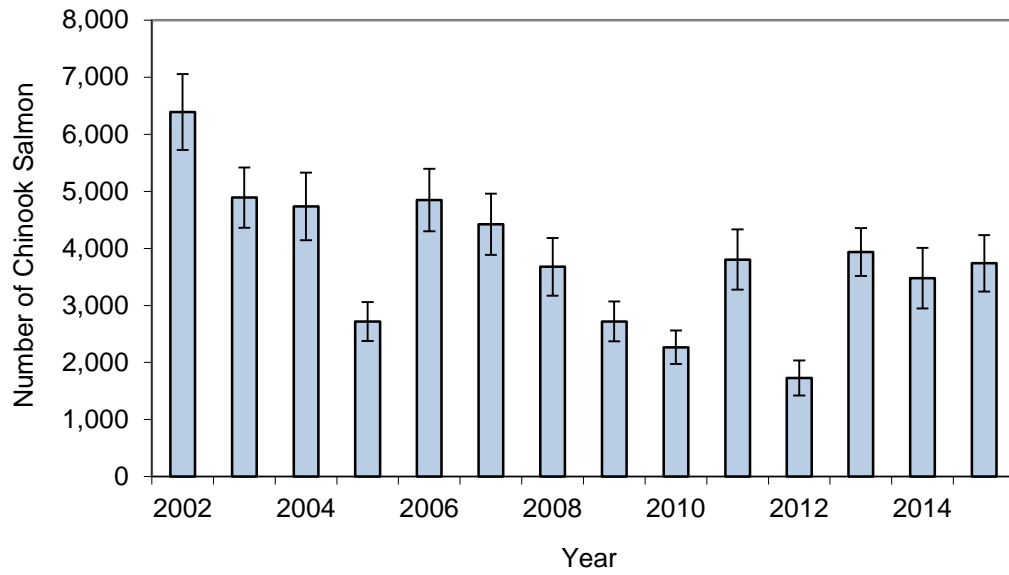


Figure 6.—Historic expanded counts of Chinook salmon with 95% confidence intervals from the counting tower, Gulkana River, 2002–2015.

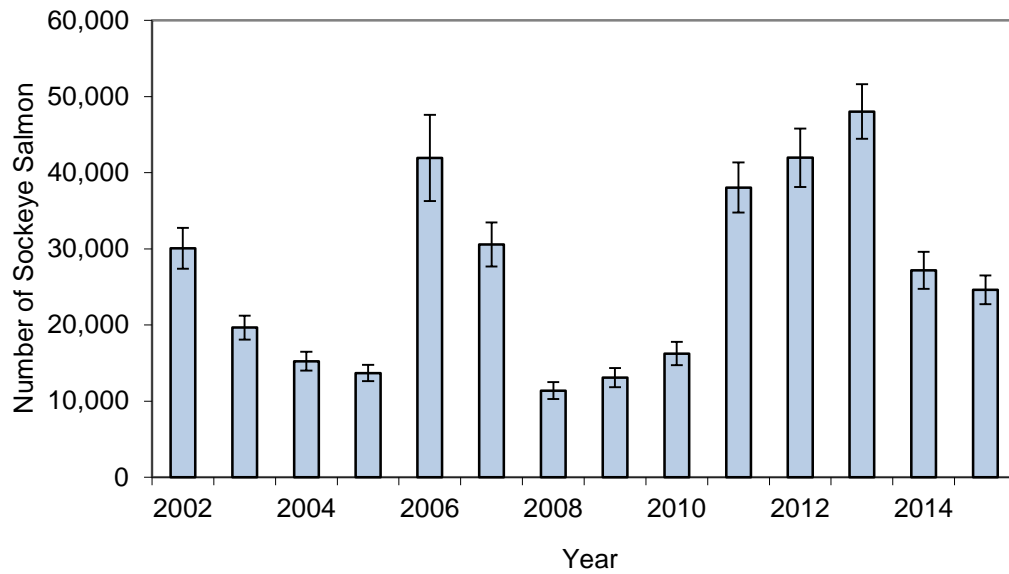


Figure 7.—Historic expanded partial counts of sockeye salmon with 95% confidence intervals from the counting tower, Gulkana River, 2002–2015.

The main objective of an escapement monitoring project is to estimate total escapement for a particular stock, or provide an index of escapement that is relatively consistent over time with respect to the proportion of the escapement that is enumerated. The counting tower has always done well counting Chinook salmon during the entire duration of the run, because counting typically starts days before the first salmon is counted and ends days afterwards. It was believed during the inception of this project and for many years that the counting tower did count the majority of the run. Anecdotal information from sport fishers and guides, and results from previous aerial surveys (Taube 2002) and radiotelemetry studies (Savereide 2005) indicated that the majority (>80%) of spawning in the Gulkana River drainage occurred upstream of the selected tower site. ADF&G (unpublished data) estimated that 81%, 86%, and 50% of the Gulkana Chinook salmon spawned above the counting tower site in 2002, 2003, and 2004, respectively. It was assumed that >80% was normal and that the disparity in 2004 was caused by an unusually warm, dry summer and the associated very warm (20–24 °C) and low water conditions hindered Chinook salmon passage in the Gulkana River (Maclean 2013).

Since 2010 anecdotal reports of angling remaining good later than usual below the West Fork Gulkana River confluence have increased (i.e., until the fishery closed on 19 July) and ADF&G counting tower staff started to notice more fish below the counting tower later than usual (i.e., well into August). A Chinook salmon telemetry study was conducted from 2013 through 2015 to address what proportion of the total escapement was passing upstream of the counting tower. Results are still preliminary, but in all 3 years about 50% of the radiotagged fish spawned below the counting tower, similar to what was found in 2004 (Schwanke *In prep*).

It appears that a change in Chinook salmon spawning distribution has taken place on the Gulkana River, and this perception is supported by the counting tower data, the radiotelemetry study, and the anecdotal angler information. It is clear that Chinook salmon runs are later than when this project first started; examining the date at which 75% of passage was reached shows an obvious trend of fish arriving later to the tower site (Table 4). For the first 7 years of the study, the 75th percentile was reached no later than 17 July, but the last 6 years of the study the 75th percentile has been reached no sooner than 20 July (Figure 8). It is plausible that fish passing later is reflective of a greater proportion now spawning closer to the tower site location.

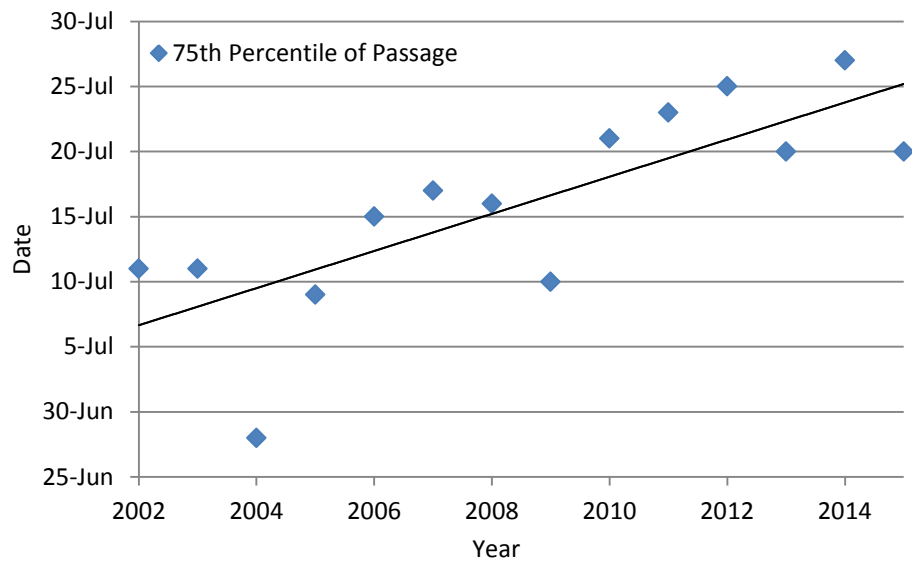


Figure 8.—Date of 75th percentile of Chinook salmon passage past the counting tower, Gulkana River, 2002–2015.

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